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Description

TUBE BUNDLE HEAT EXCHANGER

The invention relates to a tube bundle heat exchanger having at least one channel that carries a heating or cooling medium, in particular, a heating gas, whereby the tubes of the tube bundle extend essentially axis-parallel to the channel longitudinal axis through the channel, and the heating or cooling medium is directed through rings and discs, which are arranged on and fastened to the respective jacket walls of the channel in an alternating fashion, in a zigzag pattern as seen in the axial direction of the channel, through the channel which exhibits an essentially annular cross section.

Tube bundle heat exchangers through which various gaseous and/or liquid media flow on the tube and jacket side (channel side) are required for many chemical and petrochemical processes. In conjunction with that, installed on the channel side at certain intervals inside the channel in order to increase the heat transmission coefficient of the heat exchanger and support the tube bundle tubes inside the channel are baffles (rings and discs) that help to create between the baffles a heating or cooling medium flow that is directed transversely to the tube bundle tubes or heating surface tubes. This flow component can act upon the heating surface tubes with pulsating forces such that they are induced to oscillate and, in the worst case, are mechanically loaded by constant oscillation, particularly in the resonant range of the tubes.

The natural frequency of the tubes is primarily determined by the tube diameter, the wall thickness of the tubes and the interval of the support points (tube plates, baffles that support a tube). The oscillation generation frequency of the medium (heating or cooling medium) is dependent on the transverse component of the velocity of the medium and the tube spacing. If the natural frequency of the tubes matches the oscillation generation frequency, it leads to an oscillation resonance with uncontrolled high oscillation amplitudes, and as a result of that, to high mechanical loading of the tubes and a danger of cracks or other mechanical damage.

In technical practice, the danger of a resonant oscillation is usually eliminated with the aid of an oscillation analysis, which should be carried out in accordance with the TEMA (Tubular Exchanger Manufacturers Association) Standard, for example, or another recognized method. In order to eliminate the resonant oscillation, it is often necessary to stiffen the natural oscillation of the tubes by means of very short support point intervals. Since the edge tubes, i.e., the tubes lying in the area of the outer or inner jacket region, are held by every second baffle and thus on the channel side, the outer tubes of a tube bundle are held by the ring plates or rings and the inner tubes of the tube bundle are held by the discs, the baffle intervals become or would become very close to each other, which leads or would lead to a large pressure loss on the jacket side.

From the brochure "Process Gas Waste Heat Recovery Systems for Ammonia, Methanol, Hydrogen and Coal Gasification Plants," Deutsche Babcock, Babcock-Borsig, page 14, a tube bundle heat exchanger with two gas channels and baffles has become known, in which on the channel side the outer tubes of the tube bundle are held by ring plates and the inner tubes of the tube bundle are held by discs.

The task of the present invention is to create a tube bundle heat exchanger that avoids the disadvantages mentioned above, and to securely support the particular tubes of the tube bundle inside the channel or channels and to prevent oscillation resonances on the tube bundle tubes that can lead to mechanical damage.

The task mentioned above is solved through the characterizing features of patent claim 1. In that regard, the solution provides that in at least one channel, the rings and discs accommodate and position all of the tubes of a channel by means of cylindrical recesses or bores, and the perimeter contour of each of the rings and discs on the medium flow-through side follow the

Midpoints of the outermost or innermost tube bundle tubes, whereby the perimeter contour includes a web that surrounds all of the outermost or innermost tubes.

Advantageous designs of the invention can be found in the dependent claims.

Created by means of the inventive solution is a tube bundle heat exchanger that exhibits the following advantages:

- all of the tube bundle tubes are securely supported and positioned within the channel,
- all of the tubes are supported in such a way that the frequency of the first harmonic oscillation of the tubes is in all cases above the generation frequency of the tubes resulting from the medium flow, and as a result of that, no oscillation resonance occurs on the tube bundle tubes,
- despite smaller support intervals of the individual tubes, the medium pressure loss is increased only insignificantly, if at all.

In an advantageous way, the width of the web as the distance between the outer wall of the tube and the perimeter contour is at least partially constant. This means that in the case of the aforesaid regions between the mid-point or the outer wall of the outermost and innermost tubes, the same distance prevails to the perimeter contour, which represents a simplification from the design and manufacturing perspectives.

In an advantageous further development of the invention, the width of the web is between 3 and 10 millimeters. This further development makes it possible for not only the inner and central tubes of the tube bundle to be securely accommodated and positioned, but also the outermost and innermost tubes of the particular channel. In a particularly advantageous further development, the width of the web is made less than 3 millimeters. With this design, a

maximum of free passageway cross section of the heating or cooling medium is achieved on the flow-through side of the rings and discs.

Through an at least partially undulating perimeter contour that follows the outer contour of the outermost or innermost tubes, a design of the rings and discs can be achieved that is advantageous in terms of manufacture, a constant flow-through cross section, etc. It can be advantageous, or additionally advantageous, that the perimeter contour runs at least partially parallel to an imaginary line connecting two or more outer or inner tube mid-points. This is advantageous when sufficient flow-through cross section is available at the rings and discs, and the perimeter contour thus does not have to follow each individual tube cross section.

If more than one channel is present inside the tube bundle heat exchanger, two or more channels are arranged concentric to each other. A compact heat exchanger is achieved through this measure.

In an advantageous way, if two or more channels are present, the rings and discs designed with the perimeter contour are arranged in the outer channel or channels. Through this measure, the pressure loss in the heating or cooling medium that is caused by the baffle ring and disc can be kept small.

In an advantageous design, the tubes of the particular tube bundles can be configured as U-tubes or straight tubes. Heat exchangers according to the invention can thus be equipped with tube bundles of varying designs, and can thus be used for the widest variety of applications.

It can be advantageous to design the inventive rings and/or discs with a crescent shape. Particularly in the case of tube bundle heat exchangers with straight tubes (instead of the

U-tubes), this leads to a stronger transverse incoming flow of the tubes and thus to greater heat transmission.

In an advantageous design, on the cross-section side the tubes are arranged inside the channel in a spacing or structure with a triangular or square or other geometrical shape. The triangular spacing or structure is particularly advantageous at high pressures in heat exchangers, since a significantly more highly stiffened tube plate can be achieved. Square or other geometrical structures or tube spacings are advantageous for moderate and low pressures.

In the following, embodiments of the invention are described in more detail with the aid of the drawing and the description.

Shown are:

Fig. 1, a longitudinal section through a tube bundle heat exchanger according to a state of the art,

Fig. 2, a longitudinal section through a tube bundle heat exchanger according to the invention,

Fig. 3, a partial cross section according to section A-A in Figure 2,

Fig. 4, a partial cross section according to section B-B in Figure 2,

Fig. 5, an enlarged detail view C according to Figure 3,

Fig. 6, an enlarged detail view D according to Figure 3,

Fig. 7, as Figure 5, but tube bundle tubes inside the channel laid out with a different (square) geometric structure,

Fig. 8, as Figure 3, but tube bundle tubes inside the channel laid out with a different (triangular) geometric structure,

Fig. 9, an enlarged detail view E according to Figure 8.

A tube bundle heat exchanger 1 according to a state of the art can be seen in Figure 1. Such tube bundle heat exchangers are required for the widest variety of chemical and petrochemical processes. In that regard, a heating or cooling medium 20, which is most often a heating gas, is fed through an inlet channel 18 to one or more channels or gas channels 4, 5 in which the heat or cold is conveyed to tubes or heating surface tubes 3 of a larger number of tube bundles 2 running therein which heat or cool a liquid or gaseous medium, e.g., water or steam, that is to be heated or cooled.

The design of the tube bundle heat exchanger 1 according to Figure 1 provides that the first gas channel or gas passage 4, the second gas channel or gas passage 5 and finally the outlet channel 19 are connected around the centrally arranged inlet channel 18 in a radial view and concentric to one another. In conjunction with that, the channels 4, 5, 18, 19 exhibit a common longitudinal axis 6, which corresponds to the longitudinal axis of the tube bundle heat exchanger 1. Preferably, the cross section of the inlet channel 18 is essentially round and those of the gas channels 4 and 5 as well as the outlet channel 19 are essentially annular.

The heating or cooling medium flow 20 that flows in at the one end of the tube bundle heat exchanger 1 through the inlet channel 18 is turned by 180° at the other end by the tube plate or end plate 17 that accommodates the tube bundle 2 and is directed to the first gas channel or gas passage 4. After flowing through the first gas channel 4, there is another 180° turn and

directing of the heating or cooling medium flow 20 into the second gas channel 5. Finally, after flowing through the second gas channel 5 the heating or cooling medium flow 20 is turned 180° an additional time by the tube plate 17 and is directed out of the heat exchanger 1 through the outlet channel 19.

In order to increase the efficiency of the transmission of heat or cold between the heating or cooling medium 20 and the medium that is to be heated or cooled and is circulating in the tubes 3 inside the gas channels 4, 5, and in order to support the tube bundle 2 around the tubes 3, it is provided that the tubes 3 are supported and positioned at certain intervals by means of baffles. Thus achieved is the fact that the heating or cooling medium flow 20 does not flow through the gas channel 4, 5 parallel to the tubes 3, but instead flows into the tubes 3 transversely or essentially transversely, and significantly better heat transmission is achieved in this way. The baffles are configured in such a way that at the two jacket walls 7, 8 (inner 7 and outer 8 gas channel delimitation) of the gas channel 4, 5, rings 9 and discs 10 are arranged in alternating fashion so that a zigzag pattern of heating or cooling medium flow through the gas channel 4, 5 is formed. In conjunction with that, the outer tubes 3 of the tube bundle tubes running in the gas channel 4, 5 are supported and positioned by the rings 9 fastened on the jacket wall 8, and the inner tubes 3 of the tube bundle tubes running in the gas channel 4, 5 are supported and positioned by the discs 10 fastened on the jacket wall 7. In that regard, the tubes 3 are supported by the rings 9 and the discs 10 in the axial direction, in each case at a support distance S (distance between two rings 9 or between two discs 10), whereby when viewed axially, the support of the discs 10 in each case lies midway between the support of the rings 9.

Beginning with this tube bundle heat exchanger 1 according to a state of the art, the tube bundle heat exchanger 1 according to the invention, see Figure 2, exhibits at least one gas channel 4, 5, rings 9 and discs 10, which accommodate and position all tubes 3 of the tube bundle tubes of this gas channel 4, 5, each by means of a cylindrical recess or bore 11. In addition, according to the invention the perimeter contour 12 of the rings 9 and the discs 10 on the medium flow-

through side 13 follows mid-points 14, 15 of the outermost or innermost tube bundle tubes 3, whereby the perimeter contour 12 includes a web 16 that surrounds all of the outermost or innermost tubes 3.

The medium flow-through side 13 of the rings 9 or the discs 10 involves the side 13 of the rings 9 or the discs 10 that is passed by the medium flow 20 and thus forms the free passage or passageway of the heating or cooling medium flow 20 between ring 9 and inner jacket wall 7 or disc 10 and outer jacket wall 8, see Figures 3 through 9.

The perimeter contour of the rings 9 or discs 10 on the flow-through side 13 is not designed with a circular shape, but according to the invention and as described above it follows the mid-points 14, 15 respectively of the outermost and innermost tube bundle tubes 3, i.e., the perimeter contour 12 of the rings 9 the mid-points 15 of the innermost tube bundle tubes 3 and the perimeter contour 12 of the discs 10 the mid-points 14 of the outermost tube bundle tubes 3, whereby the perimeter contour 12 additionally includes ring or disc material or a web 16, so that each individual tube bundle tube 3 is bordered or surrounded by this web 16 (see Figures 3 through 9) in order thus to securely support laterally even the innermost and outermost tubes 3. As a result of the perimeter contour 12 according to the invention, in an advantageous way the flow cross section on the flow-through side 13 of the baffles, i.e., on the rings 9 and on the discs 10, is kept as large as possible. In that regard, the width B of the material projection or web 16 between the outer wall of the outermost or innermost tube 3 and the perimeter contour 12 is preferably kept at least partially constant. Another advantageous development provides a width B of the web 16 of three to ten millimeters, and an especially preferred development provides a width B of the web 16 of less than three millimeters.

As is shown in Figures 5 and 6, the perimeter contour 12 of the rings 9 or discs 10 can follow the outer contour of the outermost and innermost tubes 3 in undulating fashion, whereby the perimeter contour 12 according to Figures 7 through 9 preferably at least partially follows the

previously mentioned tube outer contour in undulating fashion. Figures 7 through 9 show a further advantageous development of the invention, which consists in the perimeter contour 12 running at least in part parallel to an imaginary line connecting two or more outer or inner tube mid-points 14, 15. In this case, the width B of the web 16 is defined as the perpendicular distance between the perimeter contour 12 and the outer wall of the tube 3. By using the aforementioned advantageous developments, first, the rings 9 and discs 10 according to the invention can be simplified in terms of manufacturing and produced inexpensively, and second, the free passage cross section of the heating or cooling medium 20 on the flow-through side 13 of the rings 9 and discs 10 can be maximized.

In conjunction with that, the bores or cylindrical recesses 11 by means of which the rings 9 and the discs 10 are formed for accommodating all of the tubes 3 of a gas channel 4, 5 are arranged in such a way that each individual tube bundle tube 3 is accommodated and guided in the particular bores 11 of the rings 9 and discs 10, which are aligned axis-parallel to the channel or tube bundle heat exchanger longitudinal axis 6. The tubes 3 are not connected in fixed fashion with the rings 9 and discs 10, and can freely elongate axially in the bores 11 during heating in the operational state.

As a result of the inventive measure that the rings 9 and the discs 10 accommodate all of the tube bundle tubes 3 of a channel or gas channel 4, 5, the former support distance S of a given tube 3 between two rings 9 or between two discs 10 is halved to the half support distance S/2. First, this is advantageous for the lateral support of the tube bundle tubes 3, since each individual tube 3 is in practice supported twice as often as with the known versions. Second, the development according to the invention is advantageous in terms of the prevention of resonance oscillations of the tubes 3, and, as a result of that, also the prevention of the high mechanical loads on these tubes 3 that are brought about by the resonance oscillations.

An oscillation resonance on the tubes 3 forms in a known way if the natural frequency of the tubes matches the oscillation generation frequency of the medium or the heating or cooling medium 20, whereby the oscillation generation frequency of the medium is dependent on the transverse component of the velocity of the medium and the tube spacing, while the natural frequency of the tubes 3 is primarily determined by the tube diameter, the wall thickness of the tubes 3 and the interval of the support points (tube plate 17, rings 9 and discs 10).

Through the arrangement according to the invention, the oscillation resonance inside the tube bundle heat exchanger 1 can be easily prevented and the tubes 3 can be securely supported, without decreasing the intervals of the baffles, i.e., the rings 9 and discs 10, from each other, and thus creating higher pressure losses on the channel side or the heating or cooling medium side 20. As a result of the halved support intervals, if necessary it is possible to increase the dimension of the support interval or decrease the wall thickness of the tubes 3 without losing the advantageous effect.

Figures 2 through 4 reveal a tube bundle heat exchanger 1 according to the invention that is designed with, in the preferred configuration, two channels or gas channels 4, 5 that are arranged concentric to one another. In conjunction with that, in the case of two or more channels or gas channels 4, 5, the rings 9 and discs 10 that are configured with outer perimeter 12 and that accommodate all of the tubes 3 are advantageously arranged in the outer channel 5 or the outer gas channels. This measure prevents a large medium pressure loss inside the heat exchanger 1, since the medium flow 20 in the inner channel 4, in which the gas still exhibits a very high temperature and therefore possesses a large volume and a high passage velocity, finds a freer passage, i.e., a larger flow-through cross section.

While Figures 2 through 6 show a tube bundle heat exchanger 1 according to the invention, with tube bundles 2 formed from U-tubes 3 and with its inner tube field arranged in gas channel 4 and its outer tube field in gas channel 5, Figures 7 through 9 show a tube bundle heat exchanger 1 according to the invention with tube bundles 2 formed from straight pipes 3. The structural arrangement of these straight tubes 3 inside the channel 4, 5 when viewed over the cross section can be freely configured, unlike the arrangement of the U-tubes 3. On the cross-section side, the straight tubes 3 can advantageously be arranged within the channel 4, 5 in a spacing or tube structure with a triangular or square or other geometrical shape. A triangular tube spacing, as shown in Figures 8 and 9, lends itself for tube bundle heat exchangers 1 with high to very high pressures, while square tube spacings according to Figure 7 or another geometrical tube spacing lends itself for moderate and low pressures.

In the case of tube bundle heat exchangers 1 with tube bundles 2 formed from straight tubes 3, it can be advantageous to design the rings 9 and/or discs 10 with a crescent shape (not shown). This leads to a stronger transverse incoming flow of the tubes 3 by the heating or cooling medium 20, and thus to greater heat transmission as well.

The tube bundle heat exchanger 1 according to the invention is not limited to the embodiments shown in the above-mentioned Figures.

List of Reference Symbols:

1	Tube bundle heat exchanger
2	Tube bundle
3	Tube of a tube bundle
4	Channel or gas channel
5	Channel or gas channel
6	Channel longitudinal axis
7	Inner channel jacket wall
8	Outer channel jacket wall
9	Ring
10	Disc
11	Cylindrical recess or bore
12	Perimeter contour
13	Heating or cooling medium flow-through side
14	Mid-point of the outermost tubes
15	Mid-point of the innermost tubes
16	Web
17	Tube plate or end plate
18	Inlet channel
19	Outlet channel
20	Heating or cooling medium flow